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Tao et al.

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(54) **WAFER-SCALED LIGHT-EMITTING STRUCTURE**

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(30) **Foreign Application Priority Data**

Aug. 1, 2008 (TW) .... 97129479 A

(51) **Int. Cl.**
H01L 33/00 (2010.01)

(52) **U.S. Cl.** **257/98**; 438/22; 257/E33.005

(58) **Field of Classification Search** 257/98, 257/E33.005; 438/22
See application file for complete search history.

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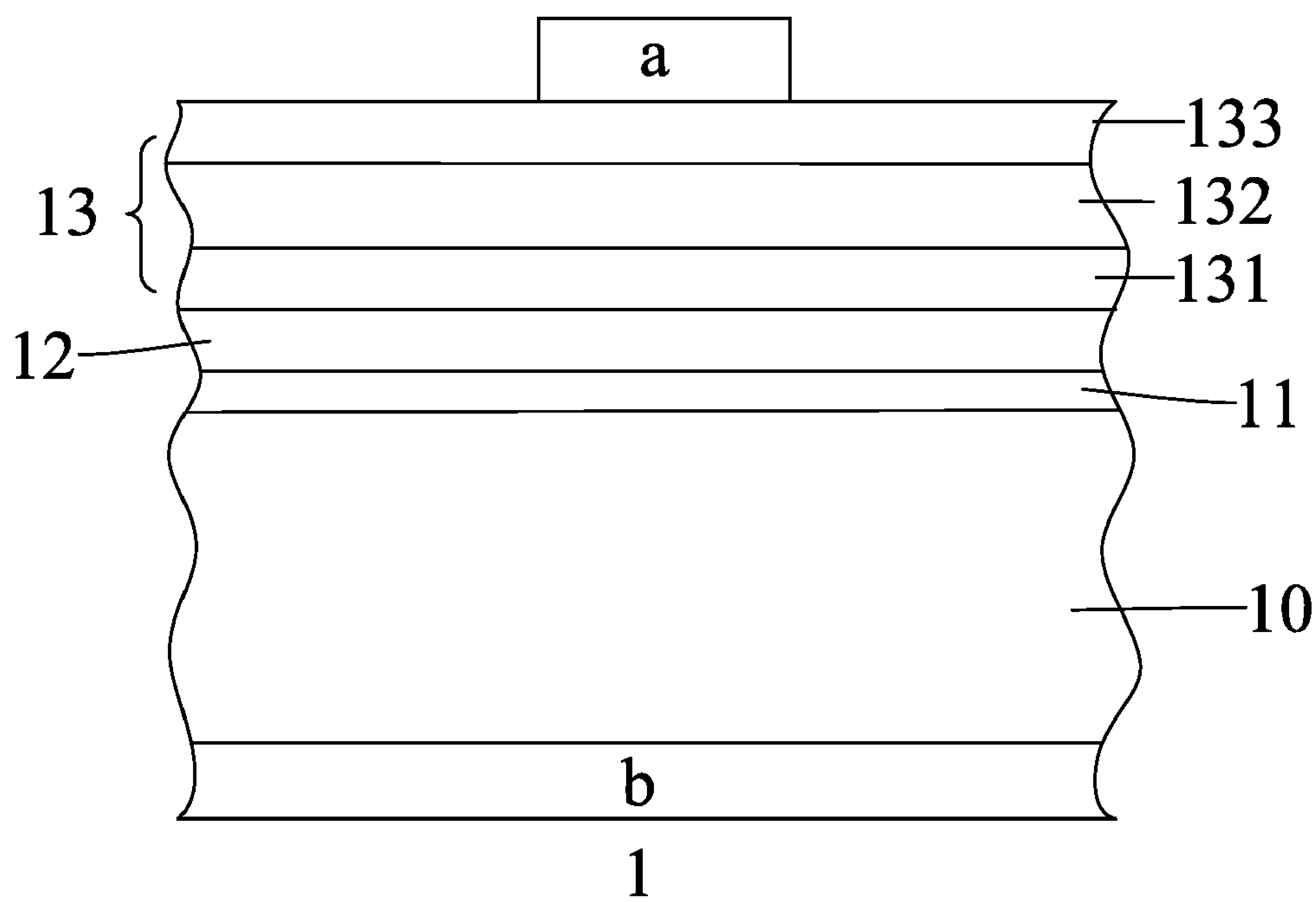
(57) **ABSTRACT**

This invention discloses a wafer-scaled light-emitting structure comprising a supportive substrate; an anti-deforming layer; a bonding layer; and a light-emitting stacked layer, wherein the anti-deforming layer reduces or removes the deformation like warp caused by thinning of the substrate.

12 Claims, 6 Drawing Sheets



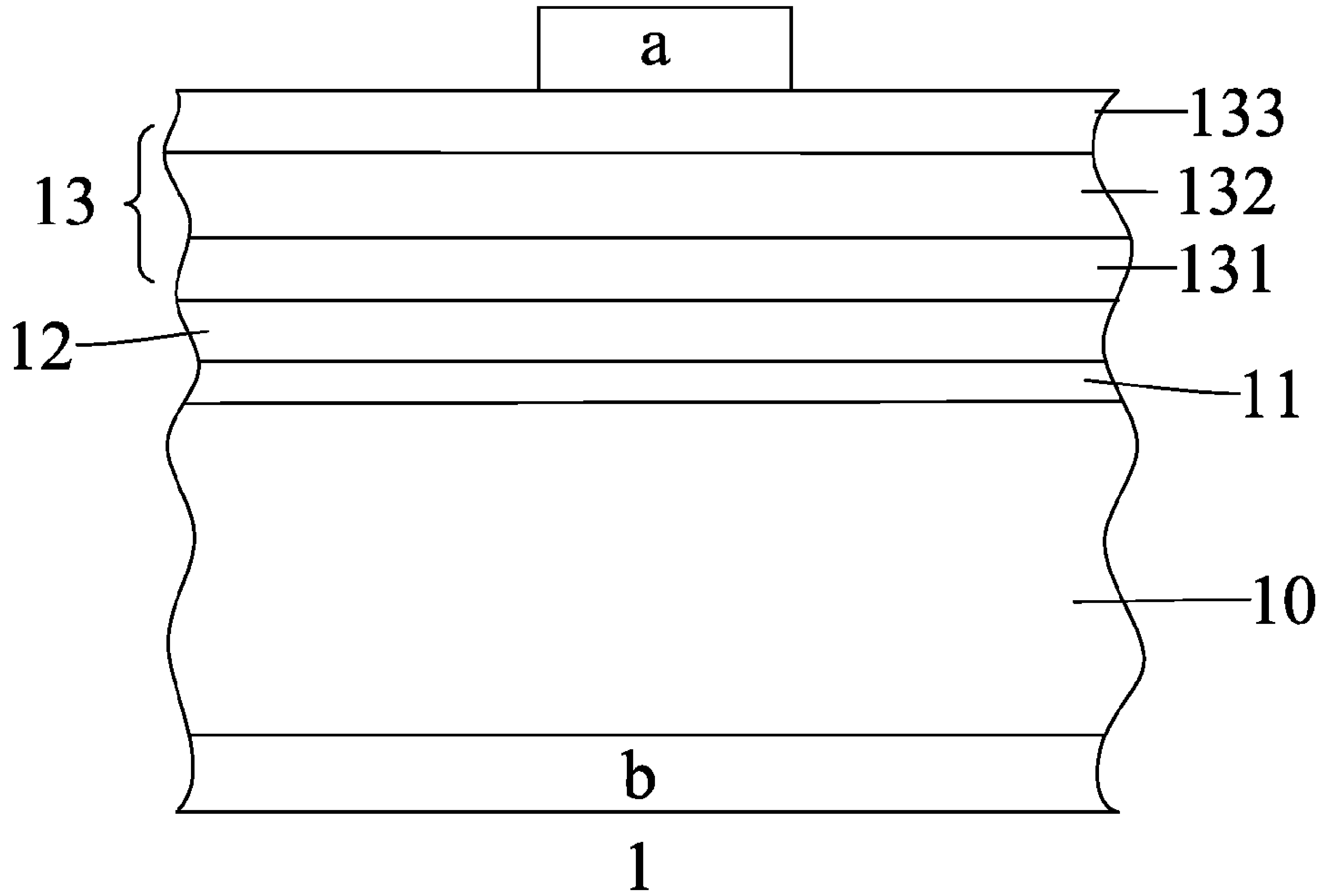


FIG.1A

Tensile Stress

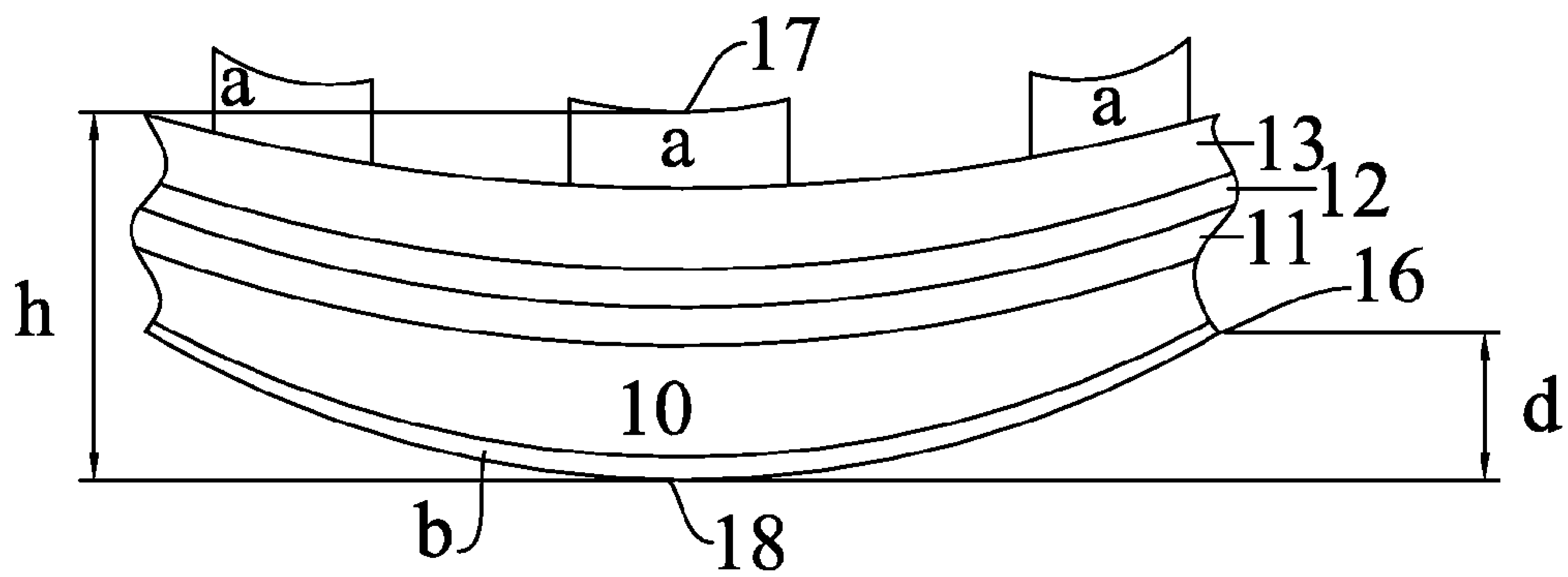
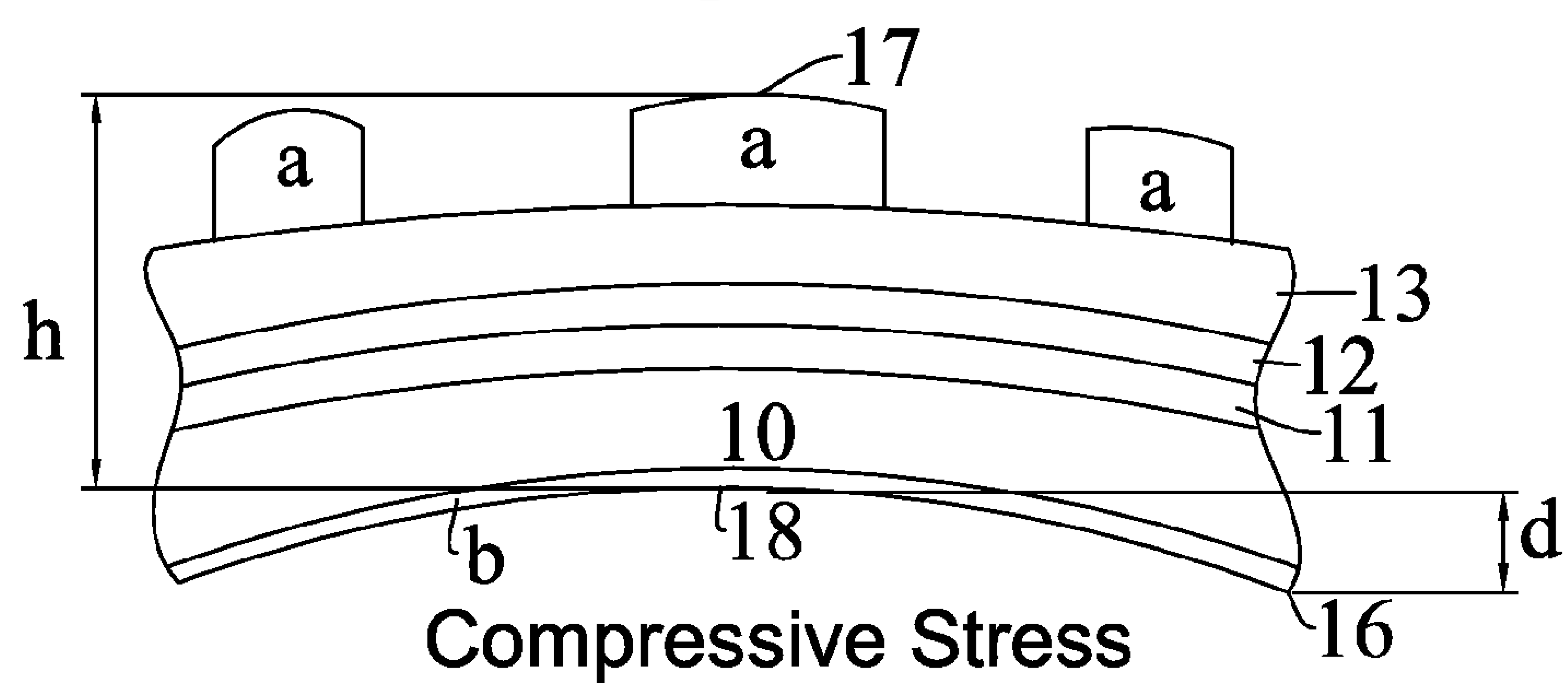


FIG.1B



Compressive Stress

FIG.1C

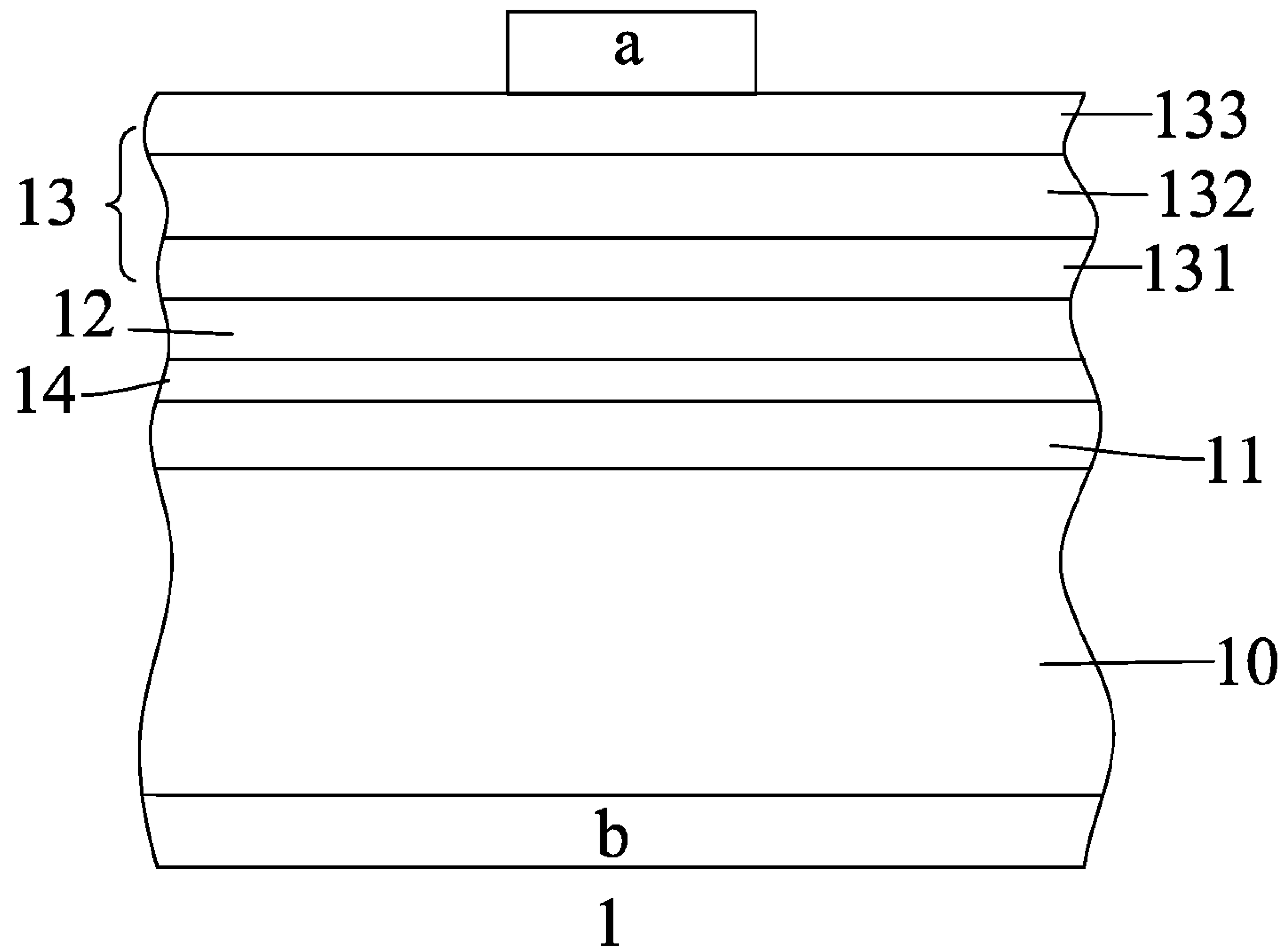


FIG.1D

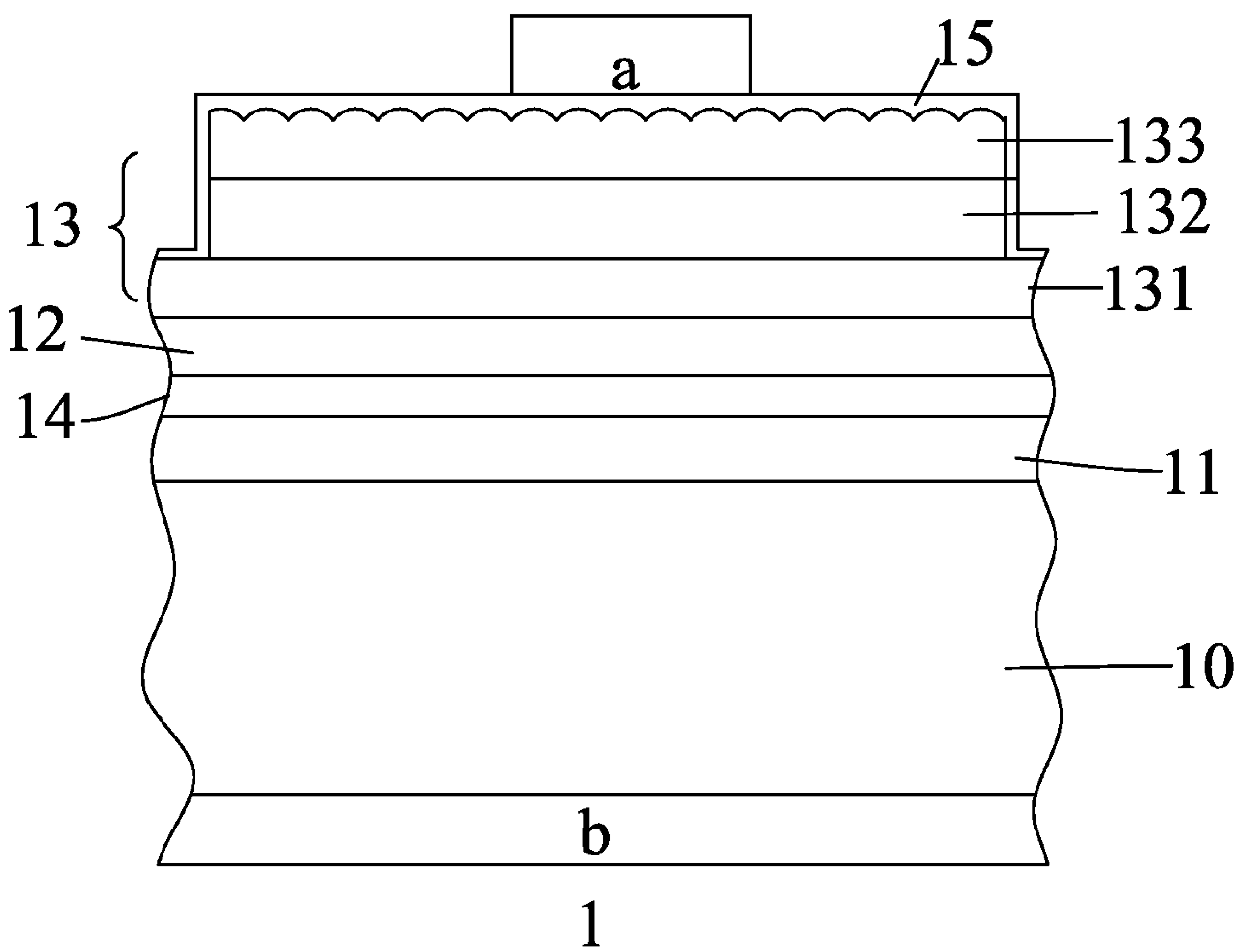


FIG.1E

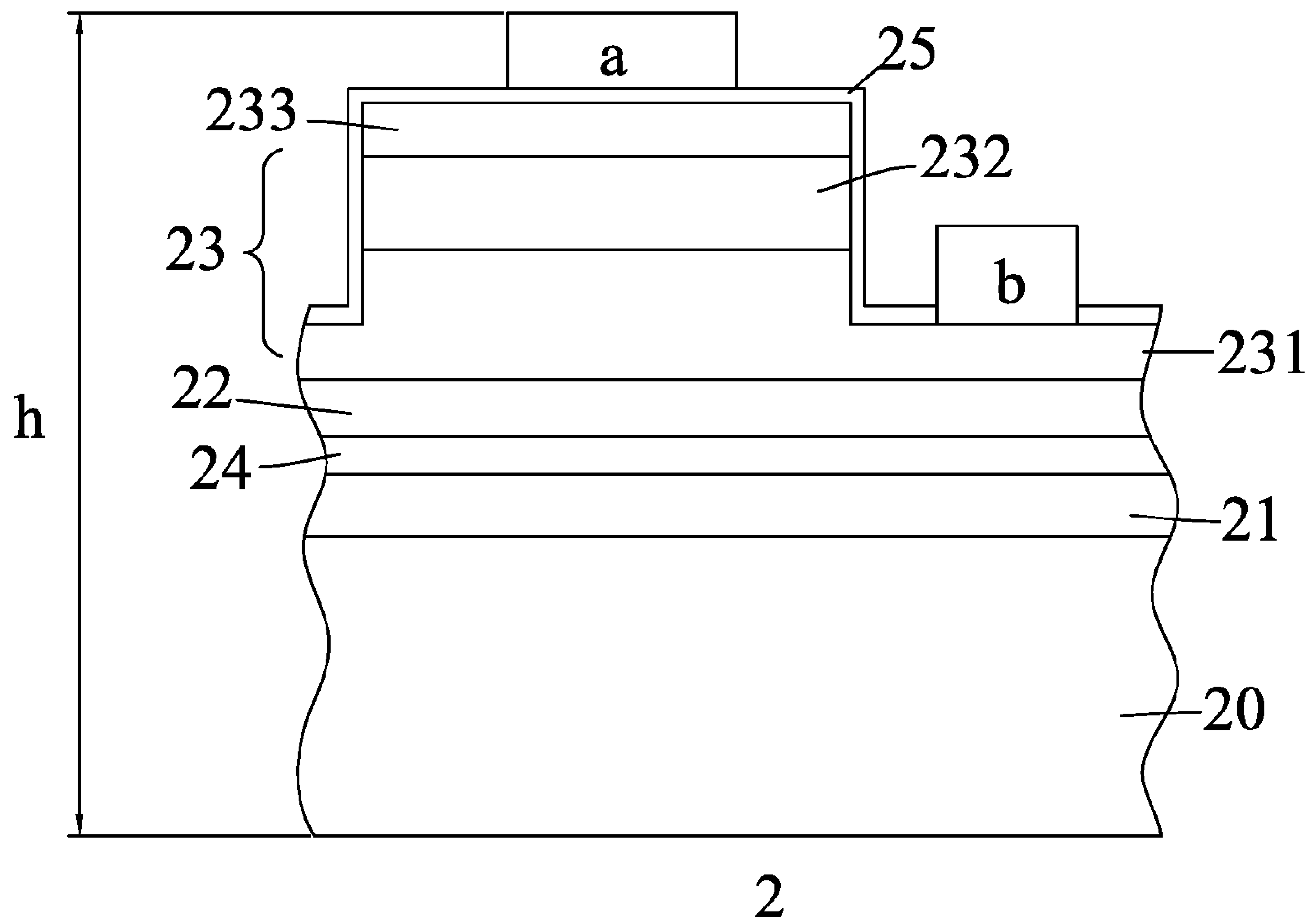


FIG.2A

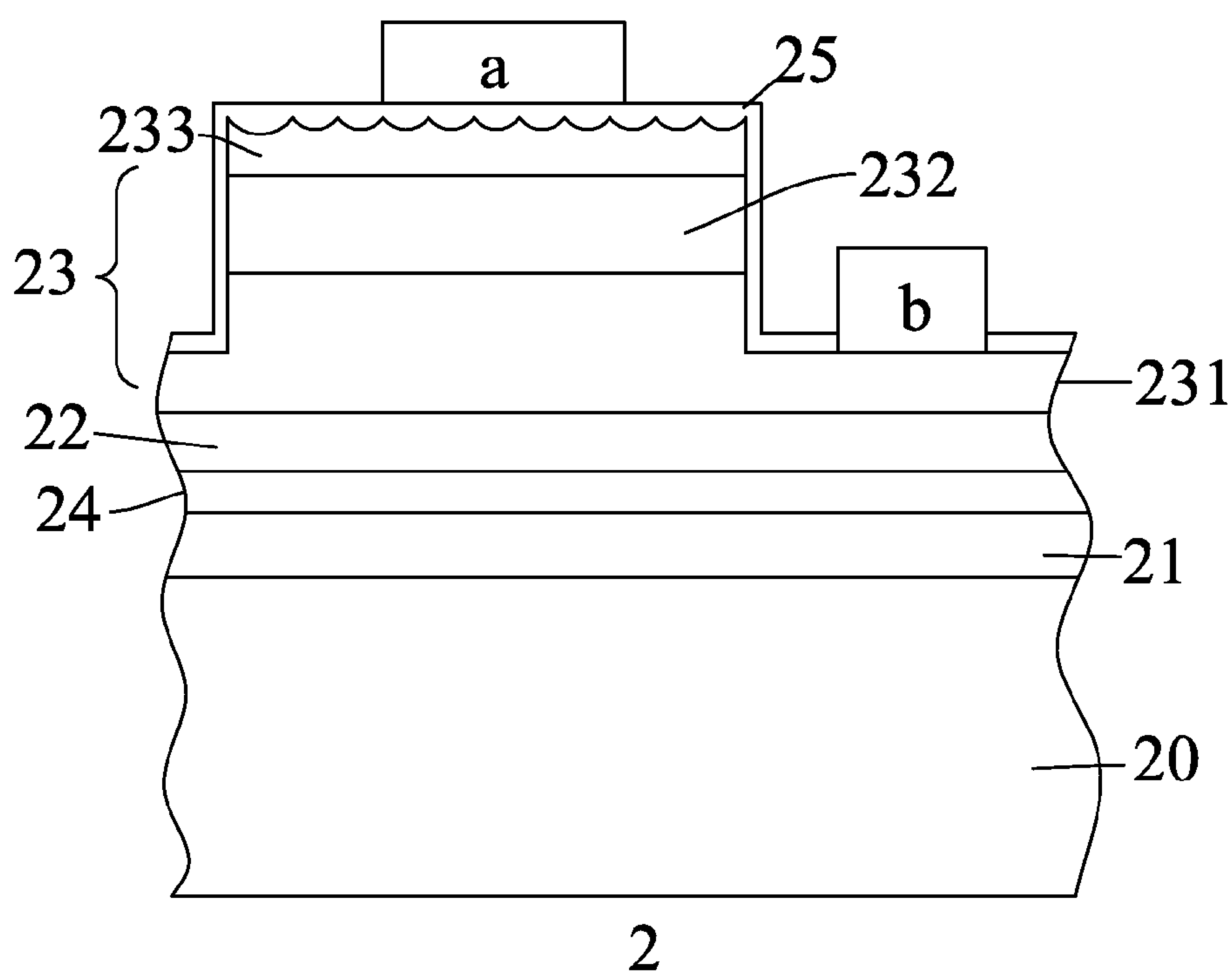


FIG.2B

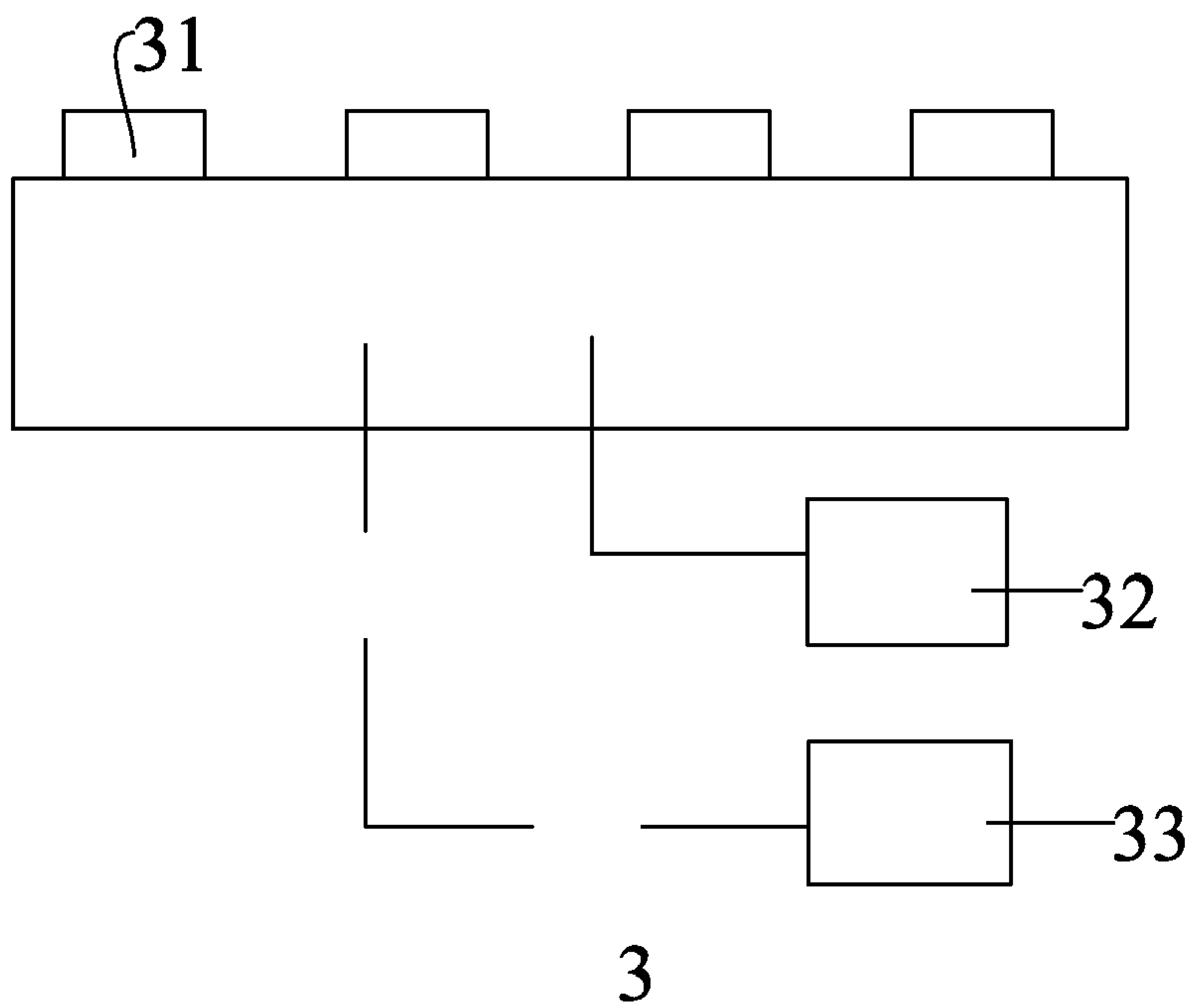


FIG.3

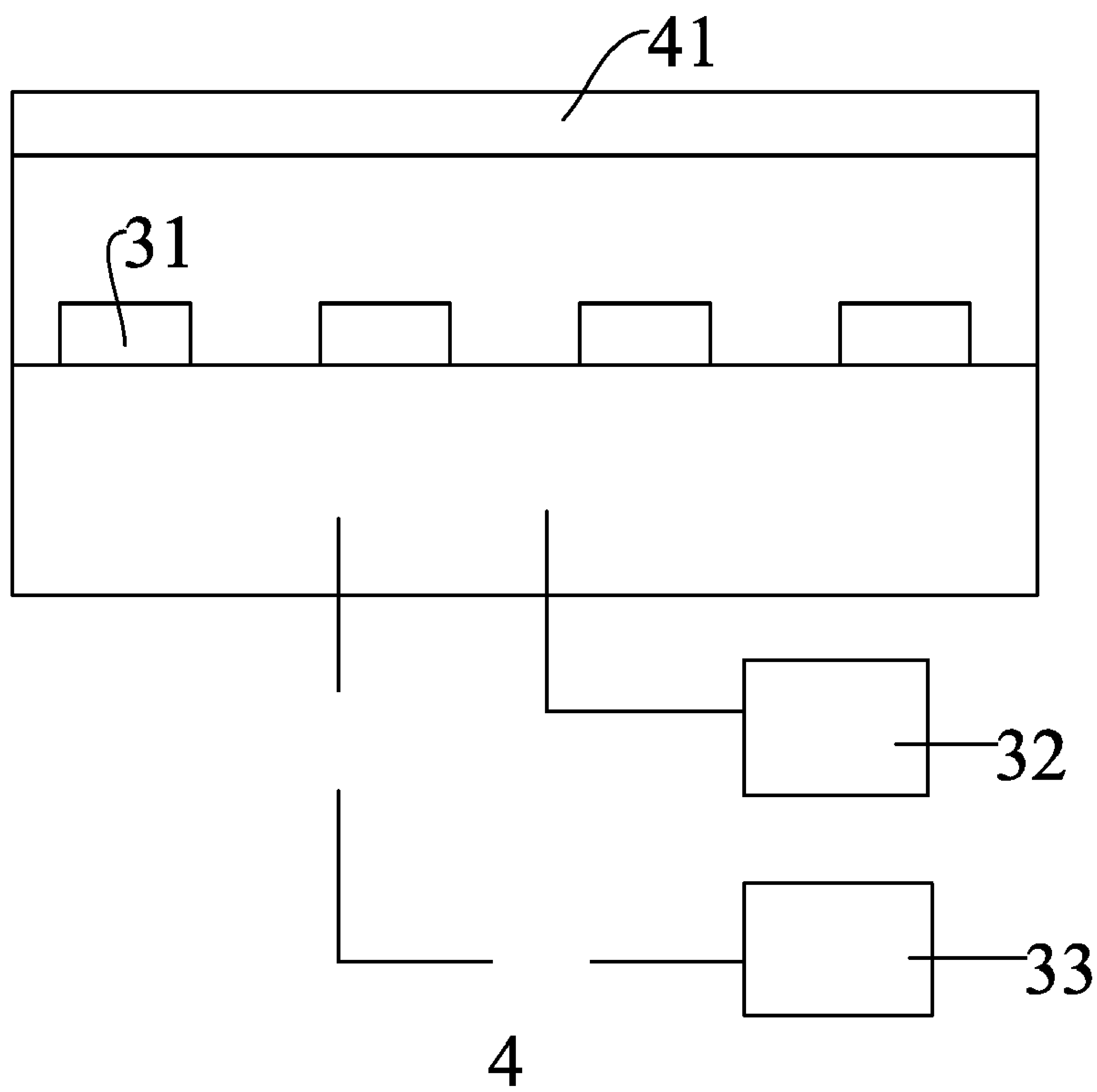


FIG.4

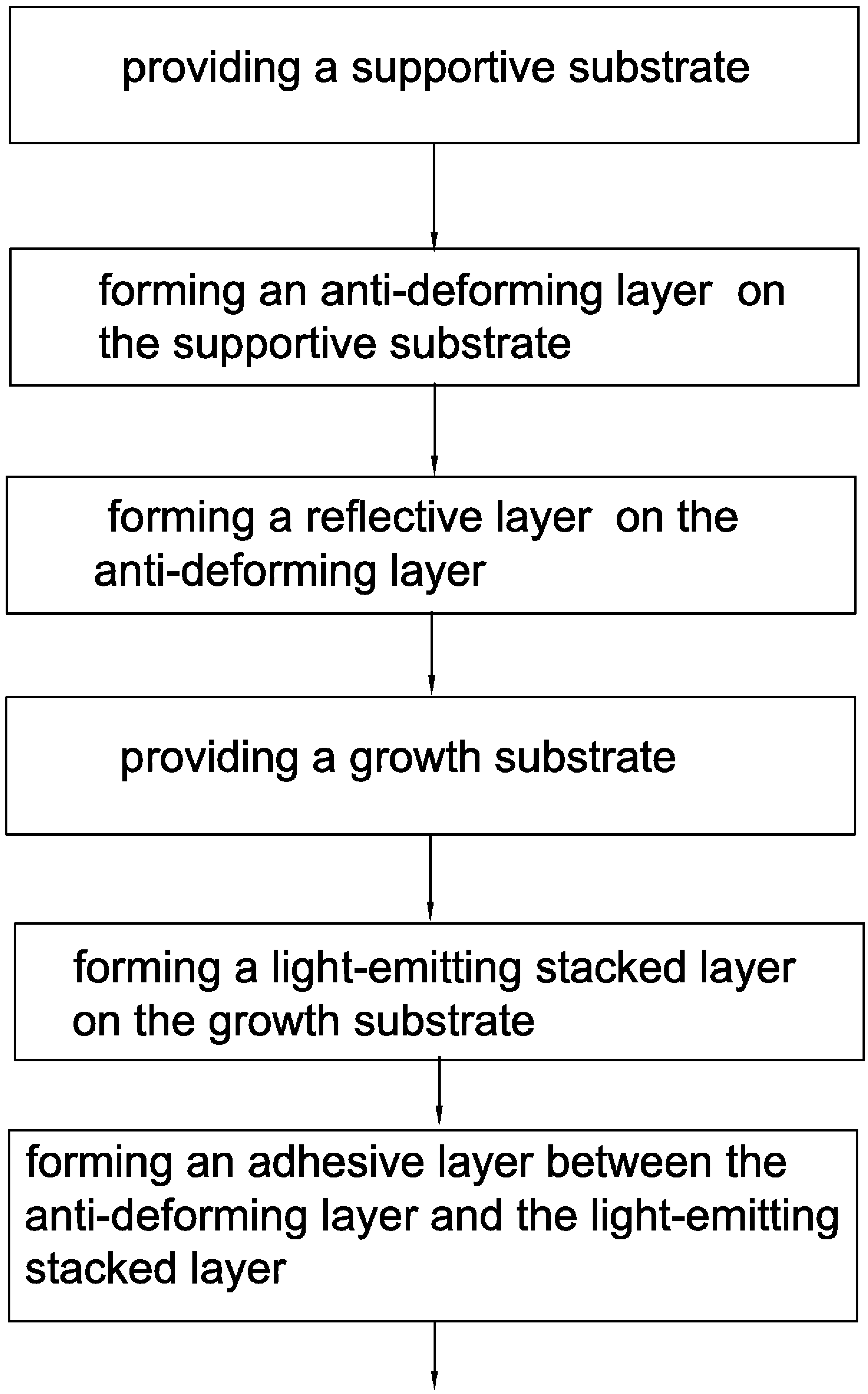

providing a supportive substrate
forming an anti-deforming layer on the supportive substrate
forming a reflective layer on the anti-deforming layer
providing a growth substrate
forming a light-emitting stacked layer on the growth substrate
forming an adhesive layer between the anti-deforming layer and the light-emitting stacked layer

FIG. 5A

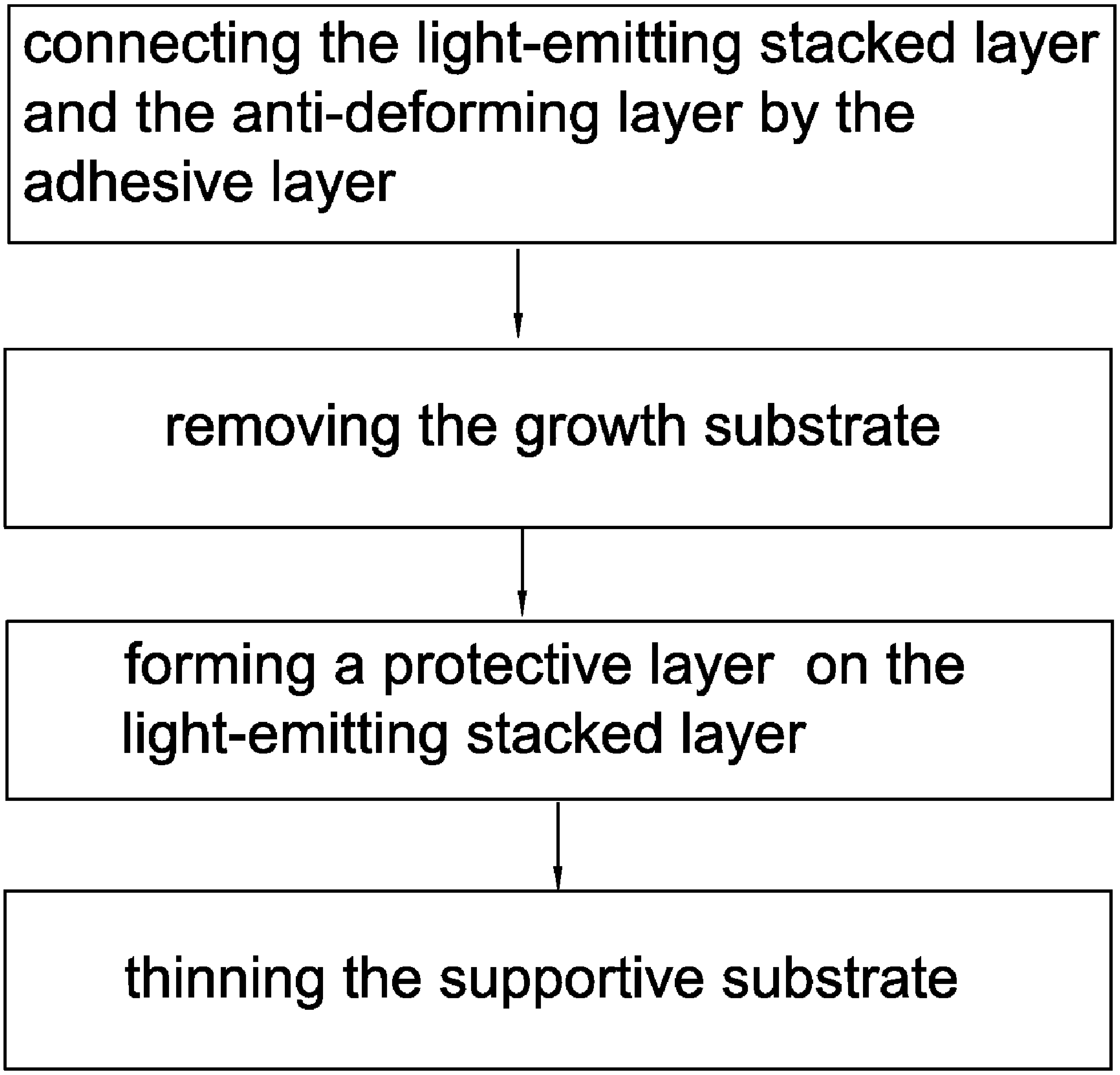

connecting the light-emitting stacked layer and the anti-deforming layer by the adhesive layer
removing the growth substrate
forming a protective layer on the light-emitting stacked layer
thinning the supportive substrate

FIG.5B

WAFER-SCALED LIGHT-EMITTING STRUCTURE

TECHNICAL FIELD

The present invention relates to a wafer-scaled light-emitting structure, especially to the wafer-scaled light-emitting structure having an anti-deforming layer.

REFERENCE TO RELATED APPLICATION

This application claims the right of priority based on TW application Ser. No. 097129479, filed "Aug. 1, 2008", entitled "WAFER-SCALED LIGHT-EMITTING STRUCTURE" and the contents of which are incorporated herein by reference.

BACKGROUND

A light emitting diode (LED) is a solid-state semiconductor element including at least a p-n junction. The p-n junction is formed between a p-type and an n-type semiconductor layers. When the p-n junction receives a suitable bias, the holes of the p-type semiconductor layer and the electrons of the n-type semiconductor layer are combined to emit light. Generally, the region emitting light is called a light-emitting region.

The characteristics of LEDs are small dimensions, high lighting efficiency, long lifetime, quick reaction, high reliability, and great chromaticity so LEDs have been applied widely in electronic devices, motor, signboard, traffic signals, and so on. With its full color spectrum, LEDs have been gradually replacing conventional lighting apparatus such as fluorescent lamps and incandescent lamps.

A liquid crystal display (LCD) has been utilized in variable kinds of electronic devices like the desktop computer or the laptop, the mobile phone, and the screens of the global positioning system (GPS) and the television. In general, the back light unit (BLU) provides a light source for LCD, and LED is one of the main light sources of the BLU. When the dimensions of the display tend toward smaller, the thinner thickness of the LED is preferred.

SUMMARY

The present application provides a wafer-scaled light-emitting structure, including a supportive substrate; an anti-deforming layer on the supportive substrate; a bonding layer on the anti-deforming layer; and a light-emitting stacked layer on the bonding layer, wherein the anti-deforming layer can reduce or remove the deformation caused by thinning of the substrate.

The present application provides a method of manufacturing a wafer-scaled light-emitting structure, including providing a supportive substrate; forming an anti-deforming layer on the supportive substrate; forming a light-emitting stacked layer on a growth substrate; forming a reflective layer on the light-emitting stacked layer; connecting the reflective layer and the anti-deforming layer by a bonding layer; removing the growth substrate; forming a protective layer on the light-emitting stacked layer; and thinning the supportive substrate. The method further includes forming a reflective layer between the bonding layer and the light-emitting stacked layer, or forming a protective layer on the light-emitting stacked layer or the supportive substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A shows a cross-sectional view of an embodiment of a wafer-scaled light-emitting structure of the present application.

FIG. **1**B-**1**C show cross-sectional views of the deformation of the embodiments of a wafer-scaled light-emitting structure of the present application.

FIG. **1**D-**1**E show cross-sectional views of the embodiments of a wafer-scaled light-emitting structure of the present application.

FIG. **2**A-**2**B show cross-sectional views of other embodiments of the wafer-scaled light-emitting structure of the present application.

FIG. **3** shows a schematic view of a light source generation device formed by a chip from dicing the wafer-scaled light-emitting structure of the present application.

FIG. **4** shows a schematic view of a BLU formed by a chip from dicing the wafer-scaled light-emitting structure of the present application.

FIGS. **5**A-**5**B show a flow chart of a method of manufacturing a wafer-scaled light-emitting structure of the present application.

DETAILED DESCRIPTION

FIG. **1**A shows a cross-sectional view of an embodiment of a wafer-scaled light-emitting structure of the present application. A wafer-scaled light-emitting structure **1** includes a supportive substrate **10**; an anti-deforming layer **11** on the supportive substrate **10**; a bonding layer **12** on the anti-deforming layer **11**; a light-emitting stacked layer **13** on the bonding layer **12**, wherein the anti-deforming layer **11** can reduce and/or remove the deformation caused by thinning of the supportive substrate **10**.

The supportive substrate **10** supports the light-emitting stacked layer **13** after removing a growth substrate of the light-emitting stacked layer **13**. The materials of the supportive substrate **10** can include but is not limited to metal, electrical insulating material, composite material, Metal Matrix Composite (MMC), Ceramic Matrix Composite (CMC), Si, IP, ZnSe, AlN, GaAs, SiC, GaP, GaAsP, Sapphire, ZnSe, ZnO, InP, $LiGaO_2$, $LiAlO_2$, or the combination thereof. After thinning the supportive substrate **10**, the thickness thereof is smaller than about 70 μm, better smaller than about 40 μm, preferably smaller than 20 μm. The thinning means reducing the thickness. For example, the surface of the supportive substrate **10** opposite to and far away from the light-emitting stacked layer **13** is polished so the thickness of the supportive substrate **10** is reduced from 300 μm to 40 μm.

The anti-deforming layer **11** contains a resistant stress to reduce the sum of the whole stress of the wafer-scaled light-emitting structure **1** after thinning the supportive substrate **10** in order to reduce or remove the deformation. The generation of the resistant stress results from the deposition defect of the molecules or the microcosmic structure of the anti-deforming layer **11**. For example, because the lattice shapes of the supportive substrate **10** and the anti-deforming layer **11** are different, the lattice mismatch is generated when the molecules bond to each other. In addition, the stacking of the molecules can form holes to result in mismatch of the molecules during the deposition process so the resistant stress can also be generated. As shown in FIG. **1**B, for example, when the supportive substrate **10** is sapphire, normally the thickness is 300 μm. However, for particular purposes like heat-dissipation, the supportive substrate **10** needs to be thinned. The thinned supportive substrate **10** can generate a stress like tensile stress to warp the supportive substrate **10** concavely so a deforming height d is generated. When the conventional wafer-scaled light-emitting structure does not include the anti-deforming layer **11**, the deforming height d is larger. For example, the deforming height d is about 1 cm that is about 200 times of a thickness h of the conventional wafer-scaled light-emitting structure. Therefore, the yield of the sequential chip process like the dicing, the breaking, or the packaging can be influenced. The deforming height d is the height from a geometry center of the bottom surface **18** to a border of the bottom surface and the lateral side of the wafer-scaled light-emitting structure **1**. The thickness h is the distance between a geometry center of the top surface **17** and the geometry center of the bottom surface **18**. Taking a circular wafer as an example in this embodiment, the geometry center of the top surface **17** and the geometry center of the bottom surface **18** can be the centers of the circles of the top surface and the bottom surface of the wafer respectively. The resistant stress of the anti-deforming layer **11** of the wafer-scaled light-emitting structure **1** is a compressive stress to reduce the deforming height d to be at most about 10 times of the thickness h of the wafer-scaled light-emitting structure **1**, better is about 5 times, preferable 0 time, for reducing or removing the deformation. When the thickness h of the wafer-scaled light-emitting structure **1** is 50 μm, the anti-deforming layer **11** can restrain the deforming height d within 500 μm. The material of the anti-deforming layer **11** can be GaN. However, in view of the material of the supportive substrate **10**, thinning the supportive substrate **10** can also generate a compressive stress to force the supportive substrate **10** to become a convex as shown in FIG. **1**C. Therefore, the material of the anti-deforming layer **11** which can generate a tensile stress should be selected to reduce or remove the deformation of the supportive substrate **10**. The thickness of the anti-deforming layer **11** can be smaller than about 30 μm, preferably is smaller than about 10 μm and larger than about 2 μm, and preferably larger than 3 μm. The anti-deforming layer **11** can be deposited on the support substrate **10** by CVD, MOCVD, VPE, LPE, MBE, PECVD, or other known deposition technologies. The material of the anti-deforming layer **11** can include but is unlimited to Al_xO_y, SiN_x, SiO_x, TiO_x, GaN, or the combination thereof.

The bonding layer **12** is utilized to connect the supportive substrate **10** and the light-emitting stacked layer **13**, and can be metal materials or non-metal materials. If the bonding layer **12** is a metal material, it can have the function of reflection. The material of the bonding layer **12** includes but is not limited to PI, BCB, PFCB, Epoxy, other organic adhesive materials, In, Sn, Al, Au, Pt, Zn, Ag, Ti, Pb, Pd, Ge, Cu, Ni, AuSn, InAg, InAu, AuBe, AuGe, AuZn, PbSn, PdIn, or the combination thereof.

The light-emitting stacked layer **13** at least includes a first cladding layer **131** located on the bonding layer **12**, an active layer **132** located on the first cladding layer **131**, and a second cladding layer **133** located on the active layer **132**. The first cladding layer **131** can be i-type, p-type, or n-type semiconductors and the conductivity of the second cladding layer **133** is different from that of the first cladding layer **131**. The structure of the active layer **132** can be single heterostructure (S H), double heterostructure (DH), double-side double heterostructure (DDH), or multi-quantum well (MQW). The material of the active layer **132** can include but is not limited to II-VI group semiconductors, CdZnSe, or III-V group semiconductors, like AlGaInP, AlN, GaN, AlGaN, InGaN, or AlInGaN.

Referring to FIG. **1**D, the wafer-scaled light-emitting structure **1** further includes a reflective layer **14** located between the light-emitting stacked layer **13** and the bonding layer **12** or the anti-deforming layer **11** and the bonding layer **12** to reflect the light emitted from the light-emitting stacked layer **13**. The material of the reflective layer **14** can include but is not limited to In, Sn, Al, Au, Pt, Zn, Ag, Ti, Pb, Ge, Cu, Ni, AuBe, AuGe, AuZn, PbSn, the combination thereof, or the DBR.

The wafer-scaled light-emitting structure **1** further includes a first pad a located on the second cladding layer **133** and a second pad b located under the supportive substrate **10** when the supportive substrate **10** is a conductor preferably. The first pad a and the second pad b electrically connect with the light-emitting stacked layer **13** and the supportive substrate **10** respectively. When the first pad a and the second pad b are located on different sides of the supportive substrate **10** respectively, the wafer-scaled light-emitting structure **1** is a vertical structure.

Referring to FIG. **1**E, the surface of the second cladding layer **133** can be roughened to form a rough surface to improve light extraction efficiency. A protective layer **15** is formed on the light-emitting stacked layer **13**, surrounds the lateral walls of the first pad a, and extends outwardly along the light-emitting stacked layer **13** to protect the light-emitting stacked layer **13** and other structures thereunder from moisture, shock, or short caused by wiring. The material of the protective layer **15** includes but is not limited to dielectric material, Su8, BCB, PFCB, Epoxy, Acrylic Resin, COC, PMMA, PET, PC, Polyetherimide, Fluorocarbon Polymer, Silicone, Glass, Al_xO_y, SiO_x, SiN_x, TiO_2, SOG, the combination thereof, or other transparent materials.

Another embodiment of a wafer-scaled light-emitting structure **2** as shown in FIG. **2**A includes a supportive substrate **20**; an anti-deforming layer **21** located on the supportive substrate **20**; a reflective layer **24** located on the anti-deforming layer **21**; a bonding layer **22** located on the reflective layer **24**; a light-emitting stacked layer **23** located on the reflective layer **24**; and a protective layer **25** located on the light-emitting stacked layer **23**, wherein the anti-deforming layer **21** can reduce or remove the deformation caused by thinning of the substrate.

The supportive substrate **20** supports the light-emitting stacked layer **23** after removing a growth substrate of the light-emitting stacked layer **23**. After thinning the supportive substrate **20**, the thickness thereof is smaller than about 70 μm, better is smaller than about 40 μm, preferably is smaller than 20 μm. The thinning means reducing the thickness. For example, the thickness of the supportive substrate **20** is reduced from 300 μm to 40 μm. The anti-deforming layer **21** contains a resistant stress to reduce the sum of the whole stress of the wafer-scaled light-emitting structure **2** after thinning the supportive substrate **20** in order to reduce or remove the deformation. In this embodiment, the thickness of the anti-deforming layer **21** can be smaller than about 30 μm, preferably is smaller than about 10 μm and larger than about 2 μm, and preferably is larger than 3 μm. The thinned supportive substrate **20** can generate a deforming height. When the conventional wafer-scaled light-emitting structure does not include the anti-deforming layer **21**, the deforming height is larger. For example, the deforming height is about 1 cm that is about 200 times of a thickness of the conventional wafer-scaled light-emitting structure. The deforming height is the height from a geometry center of the bottom surface to a border of the bottom surface and the lateral side of the wafer-scaled light-emitting structure **2**. The thickness h is the distance between a geometry center of the top surface and the geometry center of the bottom surface. Taking a circular wafer as an example in this embodiment, the geometry center of the top surface and the geometry center of the bottom surface can be the centers of the circles of the top surface and the bottom surface of the wafer respectively. The anti-deforming layer **21** can reduce the deforming height to be at most about 10 times of the thickness of the wafer-scaled light-emitting structure **2**, better is about 5 times, preferably is about 0 time, for reducing or removing the deformation. When the thickness of the wafer-scaled light-emitting structure **2** is 50 μm, the anti-deforming layer **21** can restrain the deforming height within 500 μm. The bonding layer **22** is utilized to connect the supportive substrate **20** and the light-emitting stacked layer **23**, and can be metal materials or non-metal materials. The reflective layer **24** can reflect the light emitted from the light-emitting stacked layer **23**. The protective layer **25** is formed on the light-emitting stacked layer **23**, surrounds the lateral walls of a first pad a and a second pad b, and extends outwardly along the light-emitting stacked layer **23** to protect the light-emitting stacked layer **23** and other structures thereunder from moisture, shock, or short caused by wiring.

The light-emitting stacked layer **23** at least includes a first cladding layer **231**, an active layer **232**, and a second cladding layer **233**. When the light-emitting stacked layer **23** is etched to expose a part of the first cladding layer **231**, the first pad a is located on the second cladding layer **233** and the second pad b is located on the exposed part of the first cladding layer **231**. The supportive substrate **20** is preferably insulating. For example, it can be an insulator or a conductor which is covered by an insulating layer. Referring to FIG. **2**B, the surface of the second cladding layer **233** can be roughened to form a rough surface to improve light extraction efficiency. When the first pad a and the second pad b are located on the same side of the supportive substrate **20**, the wafer-scaled light-emitting structure **2** is a horizontal structure.

FIG. **3** shows a schematic view of a light source device **3**. It includes a chip which is formed by dicing a wafer-scaled light-emitting structure in each of these embodiments of the present application. The light source device **3** can be an illuminating device such as a streetlight, a vehicle light, or indoor light source, a traffic light, or a backlight source of a BLU of a panel display. The light source device **3** includes a light source **31** composed of the aforementioned chip, a power supply system **32** offering a current to the light source **31**, and a control element **343** to control the power supply system **32**.

FIG. **4** shows a schematic view of a BLU **4**. It includes the aforementioned light source device **3** and an optical element **41**. The optical element **41** processes the light form the light source device **3** to apply to the panel display. For example, the optical element **41** can diffuse the light from the light source device **3**.

FIGS. **5**A-**5**B show a flow chart of a method of manufacturing a wafer-scaled light-emitting structure **1**. The method includes providing a supportive substrate **10**; forming an anti-deforming layer **11** on the supportive substrate **10**; forming a reflective layer **14** on the anti-deforming layer **11**; forming a light-emitting stacked layer **13** on a growth substrate; connecting the reflective layer **14** and the light-emitting stacked layer **13** by a bonding layer **12**; removing the growth substrate; forming a protective layer **15** on the light-emitting stacked layer **13**; thinning the supportive substrate **10**; and dicing the wafer to form chips. In addition, a reflective layer **14** can also be formed between the light-emitting stacked layer **13** and the bonding layer **12**. After the reflective layer **14** is formed on the light-emitting stacked layer **13**, the bonding layer **12** connects the reflective layer **14** and the anti-deforming layer **11**. The bonding layer **12** can be formed on the anti-deforming layer **11** and the light-emitting stacked layer **13** respectively and then connect the anti-deforming layer **11** and the light-emitting stacked layer **13**. The anti-deforming layer **11** can be deposited on the supportive substrate **10** by CVD, MOCVD, VPE, LPE, MBE, PECVD, or other known deposition technologies. The material of anti-deforming layer **11** can include but is not limited to Al_xO_y, SiN_x, SiO_x, TiO_x, GaN, or the combination thereof. The method of thinning the supportive substrate **10** can include but is not limited to Chemical Mechanical Polishing (CMP) or etching.

It should be noted that the proposed various embodiments are not for the purpose to limit the scope of the application. Any possible modifications without departing from the spirit of the application may be made and should be covered by the application.

What is claimed is:

1. A light-emitting structure, comprising:

a supportive substrate;

an anti-deforming layer for reducing the deformation of the light-emitting structure located on the supportive substrate;

a bonding layer located on the anti-deforming layer; and

a light-emitting stacked layer located on the anti-deforming layer, wherein the bonding layer connects the anti-deforming layer and the light-emitting stacked layer and the light-emitting stacked layer comprises at least an active layer;

wherein a thickness of the supportive substrate is smaller than about 70 μm, and

wherein the light-emitting structure is devoid of any substrate comprising a surface on which the light-emitting structure is grown.

2. The light-emitting structure as described in claim **1**, wherein a material of the supportive substrate is selected from a group consisting of metal, electrical insulating material, composite material, metal matrix composite (MMC), ceramic matrix composite (CMC), Si, IP, ZnSe, AN, GaAs, SiC, GaP, GaAsP, Sapphire, ZnSe, ZnO, InP, $LiGaO_2$, $LiAlO_2$, and the combination thereof.

3. The light-emitting structure as described in claim **1**, wherein the thickness of the supportive substrate is about 40 μm.

4. The light-emitting structure as described in claim **1**, wherein a material of the anti-deforming layer is selected from a group consisting of Al_xO_y, SiN_X, SiO_x, TiO_x, GaN, and the combination thereof.

5. The light-emitting structure as described in claim **1**, wherein the anti-deforming layer comprises a deposition defect of molecules or a microcosmic structure.

6. The light-emitting structure as described in claim **1**, wherein a thickness of the anti-deforming layer is either smaller than about 10 μm or larger than about 2 μm.

7. The light-emitting structure as described in claim **1**, wherein a material of the bonding layer is selected from a group consisting of PI, BCB, PFCB, Epoxy, other organic adhesive materials, In, Sn, Al, Au, Pt, Zn, Ag, Ti, Pb, Pd, Ge, Cu, Ni, AuSn, InAg, InAu, AuBe, AuGe, AuZn, PbSn, PdIn, and the combination thereof.

8. The light-emitting structure as described in claim **1** further comprising a reflective layer located between the light-emitting stacked layer and the bonding layer or between the anti-deforming layer and the light-emitting stacked layer.

9. The light-emitting structure as described in claim **8**, wherein a material of the reflective layer is selected from a group consisting of In, Sn, Al, Au, Pt, Zn, Ag, Ti, Pb, Ge, Cu, Ni, AuBe, AuGe, AuZn, PbSn, the combination thereof, and DBR.

10. The light-emitting structure as described in claim **1**, wherein the light-emitting stacked layer comprises a plurality of elements selected from a group consisting of Al, Ga, In, and P.

11. The light-emitting structure as described in claim **1** further comprises a protective layer located on the light-emitting stacked layer.

12. The light-emitting structure as described in claim **11**, wherein a material of the protective layer is selected from a group consisting of dielectric material, Su8, BCB, PFCB, Epoxy, Acrylic Resin, COC, PMMA, PET, PC, Polyetherimide, Fluorocarbon Polymer, Silicone, Glass, Al_xO_y, SiOx, SiN_x, TiO_x, SOG, the combination thereof, and other transparent materials.

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